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SNOWDRIFT CONTROL ON HIGHWAYS BY PLANTING OF TREES AND SHRUBS

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INTRODUCTION

In recent years the planting of trees and shrubs along highways has received considerable attention. The main reason, of course, has been beautification, but in some instances this has been combined with snowdrift control in a dual purpose planting.

Much literature is available on the planting of trees and shrubs for shelterbelt purposes to protect farmsteads, minimize snow drifting against farm buildings or into feed lots, to protect crops and to reduce wind erosion on agricultural fields. Information dealing specifically with this problem in relation to highway planting is more meager, especially as regards the actual type of snow profile formed by tree belts of varying width, composition and density.

Finney[3] has performed a number of experiments in a wind tunnel whose cross section was 2 feet by 2 feet and in which various designs, widths and densities of model windbreaks were tested to determine their effect on the snow profile. He used flake mica and balsam wood sawdust as snow, and found that the effective area ranged from 11 to 15 times the height of the barrier. A spacing distance between trees in the rows of 1.1 times the diameter of the crown gave best results. Staggered trees increased effectiveness of the barrier. There was apparently little to be gained by using more than 3 rows of trees.

Data by Russian investigators on type of snow profile formed by several types of closely spaced belts showed from 5 to 10 feet of snow accumulation in the belts with practically all of it lodged within 70 to 80 feet of the first shrub row,[4] that being on the windward side of the belt.

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[3] Finney, E. A. Snow control by tree planting. Michigan Engr. Exp. Station, Bul. 57. July 1937

The distance of effectiveness of a barrier in reducing wind velocity will depend on density and height. A reduction of as much as 53 percent of wind velocity takes place in a small zone on the lee side of the belt with about a 20 percent reduction at a distance of 15 times the height of the barrier.[5]

It is unnecessary to point out to highway workers and planners that, in the northern states, the removal of snow from highways constitutes a heavy maintenance charge; that it is especially difficult where any drifting occurs, and that a good deal of expense is incurred in the annual placing and removal of snow fences designed to keep drifts off the roads, but not always successful in doing so.

Recent trends in highway building recognize the importance of snow in blocking roads. Greater elevation of road beds, gradual slopes and smooth rounding of shoulders, and close mowing of weeds in the fall all tend to give the wind an opportunity to sweep the roadway. That is, as the saying goes, "using one's head" and making the elements help, instead of impede, traffic. But these aids, generally very helpful and sometimes fully effective in open and flat country, fail in cuts, and it is our impression that the proportion of "cuts" increases with the modern tendency to put highways straight through on low grades.

This article is inspired by the belief that snow fences composed of trees and shrubs may, in many instances, be employed with less total cost than slat-fences, although this will depend a good deal on the necessity for purchasing land therefor, as against the possibility that the farmer with abutting land may sanction the planting if he is given an interest in it. Snow fences or "traps" formed by trees may be somewhat too rigid in pattern for the best aesthetic effects, but in the windswept plains where most needed, any trees give relief to the landscape. It is our feeling that a good deal of purely ornamental planting which is being done along highways is going to prove a curse and greatly increase maintenance difficulties as the trees develop. Finally, it should be pointed out that snow traps formed by trees may be of any height desired, within natural limits, and hence of almost unlimited snow-holding capacity, whereas slat-fences have only limited effectiveness.

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[4] Rudolf, P. O. and Gevorkiantz, S. R. Shelterbelt experiences in other lands. Possibilities of shelterbelt planting in the plains region, sec. 9, p. 59-76. U. S. Forest Service special publication, 1935.

[5] Bates, C. G. U. S. Forest Service special publication, 1935. U. S. Dept. Agri. Farmer's Bul. No. 1405, Revised 1936.

The Prairie States Forestry Project (originally known as the Plains Shelterbelt Project) has encountered the snow problem both in its execution and in its research. While it cannot be said that mistakes have been entirely avoided in the placing of long belts of trees adjacent to roads, the matter has been given careful study and every effort made to avoid increasing the difficulties of keeping open primary and secondary roads in the winter, from Nebraska northward. From the research angle, contact with the problem began with a study of the behavior of wind with relation to vertical barriers, -- a study which, by determining the principles of wind movement, was expected to assist in the design of shelterbelts. Although this study was mainly prosecuted by measuring wind currents simultaneously in a great many positions on both sides of, at the ends, and above the barriers, the observation of snowdrifting helped to confirm and clarify the results of measurements, especially as the anemometers were always placed so that they measured only the horizontal element of the total wind movement. Later, special measurements were made on the accumulation of snow, which give some of the more concrete data mentioned in this paper.

BEHAVIOR OF WIND AROUND A BARRIER

Since it is believed that shelterbelt or snow-trap design can better be accomplished if any misconception as to the nature of wind is removed, it is thought worth while to state a few general facts. Engineers who have studied hydraulic principles, but have never seen the gyrations of a disturbed wind current, can recognize an extremely close parallelism. That is to say, if one considers dropping into a stream of water a thin but heavy metal plate whose height is only a fraction of the water depth, and which, by means of a flat base, may rest in a vertical position on the bottom and not be imbedded in the bed material, an almost exact replication will be produced of the disturbance in air currents caused by erection of a vertical barrier resting on the ground.

1. The current will be stopped both fore and aft (windward and leeward) yet, of course, just as much fluid will pass that section as though the barrier were not there, after the period required for adjustment, -- a slight damming effect.

2. The fluid which would normally pass through the blocked area will pass around the ends and over the top of the barrier. A slight increase in pressure and velocity at the ends and over the top of the barrier are necessary to accommodate the diverted flow. There will be a slight "hump" in the strata of water or air over the barrier, as well as outward curvature at the ends, and where the pressure is greatest, there, naturally, the velocity is greatest. As soon as the currents pass this "bottleneck" the velocity will sharply decrease, but not for a considerable distance downstream (leeward) will the current be normal throughout the entire channel.

In brief, there will be greater velocity above and around the ends of a wind barrier than would occur if it were not there, and the same is true as regards any aperture in the barrier.

3. In either the stream or this air current, velocity is much less near the bottom (ground) than at higher levels. The slight ponding effect of the submerged dam will increase the pressure at the bottom of the dam, hence the velocity next to the stream bed if there is any leakage through there. It is a well-known fact that such a dam as suggested, if placed on a sand bed, would quickly undermine, whereas the velocity at that same level had previously been sufficient only to move the sand at an imperceptible rate. Exactly the same thing occurs with a windbreak, although here it is a velocity pressure rather than a "head" pressure. A board fence resting on the ground today may be undermined tomorrow. There is a strong current under a tree windbreak unless the limbs are especially thick next to the ground. With a thin barrier, the direction tends to be diagonally downward on the windward and diagonally upward on the leeward side. This explains the fact that greatest wind reduction is often at some distance to leeward, and also the fact that snow does not pile against a fence until the drifts on both sides have exceeded the height of the fence. However, there is an eddy factor involved here also.

4. The mass of water becalmed before and behind the small dam, or of air windward or leeward of the barrier, is "enveloped," except on the ground surface, by a stream rushing forward. It is through the "drag" of this stream that the outer layers of the becalmed mass are again set in motion; with increasing distance this reaches the core of the mass, so that it tapers out and at a sufficient distance from the barrier ceases to exist. The main point of this is that the drag felt on all surfaces of the downstream or leeward air mass tends to pull it away, creating a small partial vacuum on the leeward side of the barrier, if the barrier is solid or nearly so. The effect of this vacuum on the downstream face of a submerged dam would be apparent in a swirling, gurgling eddy. One would think that the overhead stream of air, in the case of a solid wind barrier, could very readily slip into this low-pressure space. Actually, however, the velocities involved with air currents are so much greater than in a water stream, that the air stream goes a considerable distance past the barrier before bending down and turning back. Thus, in a 20-mile wind, behind a solid board fence there is found a current driving toward the earth at a distance of 5 to 7 "heights" from the barrier. This stream "mushrooms," part of it flowing back toward the low-pressure area at the barrier, and part of it moving with the overhead wind. There is actually more horizontal movement of air where this current strikes the ground than on either side; consequently, behind a solid barrier we not only find the snow piled close to the barrier, but also a secondary drift formed at a considerable distance out.

5. The type of barrier contemplated in a snow fence or a windbreak of trees is not solid, and the eddy produced by a solid barrier disappears almost entirely, because the leakage through the barrier permits no vacuum on the leeward side. There is, in all probability, a very slight eddy near the top of the barrier well above the ground.

The behavior of wind as influenced by a barrier is shown graphically in figure 1. The data for the chart were obtained on April 24, 1937, using a board fence 400 feet long which was specially constructed for the purpose of studying its effect on reduction of wind velocity and evaporation. The barrier was located on a flat, closely mowed field and consisted of 1x6-inch boards nailed vertically to a frame so as to form a 16-foot-high fence of 50-percent "density." On the date mentioned there was a steady 38-mile-per-hour wind which blew for 5.5 hours at almost exactly right angles to the board fence. To obtain the data, 100 anemometers were placed on several lines running at right angles to the barrier, some placed on the ground and some at varying distances above ground. The location of the anemometers is indicated in figure 1 by dots, beside each of which is a number indicating the velocity of the wind at that point expressed in percentage of the wind velocity -- at that same height -- of the control stations located at 20 times the height of the barrier on the windward side (Station N 20 in figure 1). The lines represent areas of equal percentage reduction of wind velocities.

Figure 1 shows that there was a 25-percent reduction in the wind velocity out to 20 times the height of the barrier, with a 74-percent reduction out to 5 heights. Zones of increased wind velocity occur at each end of the barrier and a few feet above it.

In measurement of snow profiles formed by a fence similar to the one in figure 1 but only 12 feet in height and with east-west orientation, it was found that snow piled in the zones of maximum wind reduction, with maximum height of 9.5 feet on the lee side of the belt and 6.5 feet on the windward side. The drift extended out from the barrier to a distance of about 48 feet on each side thereof with about 75 percent of the total amount of snow piled on the lee side of the fence.

SNOW PROFILES FORMED BY TREE AND SHRUB PLANTINGS

To determine the type of snow profiles in planted as compared with artificial barriers, a series of shelterbelts were cross-sectioned for snow profiles from 1937 to 1939. The shelterbelts were from 1 to 19 rows in width and embraced a wide range of ages, species, and densities. The orientation was either north-south or east-west.

The profiles and shelterbelt cross-sections are presented in figures 2 to 5 inclusive, and, except when indicated otherwise, were taken March 10 to 12, 1939. In each case the upper graph shows species used, their comparative height, density and age, as well as orientation, and directly below it is the snow profile of that belt. Measurements of snow were usually carried out on each side of the belt to a distance sufficient to get a snow depth corresponding to an average for the surrounding terrain. It must be remembered that the amount of snow accumulated in a belt may to some extent depend on the type of crop or cover on the land on the windward side and how closely it has been cut. Practically all of the belts shown in figures 2 to 5 were located on large fields which had been in wheat the previous season, and which, because of close harvesting, left a condition conducive to poor snow storage on the field and a maximum of snowdrifting.

All of the belts shown in figure 2 were comparatively young, ranging in age from 6 to 10 years. These belts are all of good design as far as present ability to accumulate snow is concerned, and several of the designs given would be quite satisfactory for highway snow traps.

The first 3 belts given in figure 2 are golden willow, which when young makes a very satisfactory snow trap even as a single row. The species, however, requires considerable moisture and should be confined to moister sites or used where a belt crosses a swale as recommended in table 1. For dry upland soils, Siberian pea, usually known as Caragana, will be just as effective as golden willow and has the advantage of being much more drought resistant.

Figure 2D represents a type of planting which is quite effective on almost any droughty upland soil in the Plains. It will be noted that the taller green ash trees seemed to aid in depositing more snow on the windward side of the belt than occurred with most of the belts.

Figure 2E is a cross-section of a belt which is ideal for farmstead planting in the Great Plains except that the isolated row of lilac (row 10) is not necessary or might have more logically been substituted for the row of gooseberry.

It will be seen in figure 2 that in all cases the first row on the windward side was low-growing and dense near the ground line. It is this first row that largely performs the task of stopping the drifting snow.

The profiles in figure 3 are for the most part in decided contrast with those in figure 2. The plantings represented are all older belts ranging from 25 to 40 years of age, except for 3B, which is a 3-year-old cottonwood belt. The tendency for these windbreaks was to allow snow to drift through the lower part of the barrier, which in the older belts of cottonwood or boxelder were devoid of limby growth, and the resulting snow deposition was a rather even layer from 10 to 20 inches deep extending out to a distance of 600 to 1000 feet beyond the trees. The deposition of the snow in an even sheet might be considered from an agronomic viewpoint as being of benefit to nearby fields, but certainly is not desirable from a highway planting viewpoint. Plantings of the type shown in figure 3 are, therefore, to be avoided. Those represented by 3D, 3E, and 3F could have been made more effective as snow traps if the outer rows had been cut back when the trees were from 2 to 5 years old, thus causing more density in the lower 10 feet of the belt.

This brings out the necessity of trimming and cutting back certain types of snow traps, particularly where species have been planted that tend to drop their lower limbs when the trees are older, and in belts which do not have at least one row of dense low-growing shrubs present. Many species which are very effective as snow traps when comparatively young will be ineffective as they grow older. A comparison of figures 2 and 3 will emphasize this point.

Figure 4 illustrates several multiple row belts containing two or more species. In figure 4A the planting has a snow trap of the type recommended by Anderson[6] and it will be seen that most of the snow accumulation occurred in the unplanted strip between the two belts. Such a design is valuable for plantings around farm buildings and gardens, but is not especially desirable or necessary for highway planting because of the amount of area required.

Figure 4B represents a design which would have been more effective with cutting back to promote limby growth near the ground line, while figure 4C represents a somewhat more effective belt but which, because of the considerable width of 220 feet, would be wider than necessary for a highway snow trap.

To determine how snow accumulated in tree belts through the winter months and how it varies from one year to the next, several snowdrifts were profiled at one- to two-week intervals. The results are plotted in figure 5.

It will be seen that in all cases the drifts accumulated much in the manner of a shifting sand dune and reached a peak height in late February or early March. For the purpose of clarity in presentation, about half of the readings are omitted from the chart, but those selected tell the story adequately.

Figure 5A is a double row of Siberian pea and represents a good design for a cheap yet effective highway snow trap. A belt of this design can easily store 6 to 8 times the maximum amount of snow recorded for February 17, 1939 and still keep the entire accumulation within 80 to 100 feet of the first shrub row on tbhe windward side.

Figure 5B is an example of a very effective snow fence planting and indicates that the type of drift formed in different years is similar as regards shape. In 1937 there was slightly more height and somewhat more width to the drifts because snowfall was heavier than in 1939.

Figures 5C and 5D are portions of the same shelterbelt, part of which was flanked on the windward side by low-growing dense willows (5D) while the other part of the belt (5C) was a pure cottonwood planting. The type of planting represented by figure 5C is extremely undesirable within a few hundred feet of the windward side of any highway because it would cause maximum deposition of snow directly on the road. Its obvious fault is lack of limbs near the ground line. In spite of great width, the 17 rows of cottonwood were not as effective in massing snow deep and close to the belt as a one- or two-row planting of Caragana.

The use of golden willow to flank the cottonwood planting shown in figure 5D proved of great value in lodging the snow close to the first row on the windward side. The golden willow in this case had been cut back when young and had retained a dense bushy growth near the ground.

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[6] Anderson, Parker. Planting the standard windbreak. Univ. of Minnesota Special Bulletin 168. August 1935.

SPECIES ADAPTED TO SNOW FENCE PLANTING

Considerable information is available regarding the species and recommended spacing of hardy trees and shrubs suitable for windbreak and shelterbelt planting, but not much of the literature deals specifically with the problem of snowdrift control on highways.

To be most satisfactory for this purpose, the species used should be low-growing, dense near the ground line, frost resistant, drought hardy, fairly free from serious rodent, insect or disease pests, adapted to a wide range of soils, and should live for at least 30 to 50 years. The ornamental value of the windbreaks, resistance to snow breakage, cost per mile of snow fence, and their possible value for cover and food for wild life are also important considerations. Very often a hedge planted for snow-trap purposes can serve a multiple use, providing the right combination of species is used.

In order to bring together the best information on this subject, the species found by actual trial and observation to be best adapted to the Northern Great Plains, especially North and South Dakota and the prairie areas of the adjoining states of Minnesota, Iowa, and northern Nebraska, are listed in table 1. It will be noted that various combinations ranging from 1 to 4 rows are given and that a considerable choice of species is listed in which hardiness, form of tree, and value for snow trap and ornamentation are considered. A few other species besides those listed could also be given, but they do not grow well throughout the entire area and can best be dealt with separately. In western Minnesota and Iowa, Black Hills spruce and northern white spruce have proved fairly good, although they do not appear to be as hardy as the Colorado blue spruce. In western Iowa the Austrian pine, and to some extent Douglas fir, have also been fairly satisfactory.

Honeylocust has been used with good success in the south half of South Dakota or its equivalent latitude in western Iowa and Minnesota. Other species could be cited as possibilities, but these are discussed in detail in the various shelterbelt planting bulletins.

Any of the one- to four-row snow fences listed in table 1 will do an excellent job of lodging snow in a zone within 40 to 80 feet of the first shrub row on the windward side in a manner illustrated in figures 5A and 5B. It will be noted that comparatively close spacing is recommended, especially within the row, in order to obtain a uniformly dense shrubby growth close to the ground. The spacing of 6 to 10 feet between rows may have to be increased to as much as 12 feet to accommodate the available cultivating equipment, but making the spacing wider than 12 feet does not seem to be advisable on the basis of existing information, except where an evergreen is planted next to a tree species like elm or boxelder, in which case it is desirable to leave a space of at least 12 and preferably 16 feet between the conifer row and the broadleaf tree species. The wide space gives the conifers a better chance of developing good form and reduces chance of overtopping of the conifers by the faster-growing adjoining hardwoods.

From the viewpoint of making a satisfactory snow trap, a single row of dense low-growing shrubs like Caragana is quite satisfactory, but from the standpoint of maximum effectiveness, two or more rows are desirable. There are a number of advantages in using belts containing 2 to 4 rows. The chief advantage is that more species can be used and this provides a considerable safety factor because gaps are not so apt to occur in a multiple-row belt because of damage to one of the species used. The use of two or more rows is also likely to create a higher aesthetic value.

In most of the planting done by the U. S. Forest Service on the Prairie States Forestry Project, each row has been devoted to a single species to simplify the planting operation, but it would undoubtedly be feasible and perhaps even desirable in plantings made primarily as snow traps to alternate species in certain rows.

The combinations in table 1 by no means exhaust the possibilities of various groupings. For instance, the 3-row belt of a shrub, low tree, and evergreen could very readily be changed by adding a flowering shrub such as lilac or American plum to row 4 to give it an even more pleasing appearance from the highway. Wider belts could be used by adopting the 7- or 9-row plan used extensively by the Prairie States Forestry Project. Every additional row, however, increases the cost of the belt without correspondingly increasing the value as a snow trap or for ornamentation.

GROUND PREPARATION, PLANTING, AND CARE OF LIVE SNOWFENCES

In the prairie and plains region, available soil moisture is the most important factor in obtaining successful establishment of tree windbreaks. It is vitally necessary that the soil have good moisture conditions at time of planting. Areas that have been in sod should be summer fallowed for at least a full year before planting and in some cases may require two years to thoroughly rot the sod and get the soil in shape for planting.

Summer fallowing might well be recommended even for areas which have been used for production of crops such as alfalfa, clover, corn or wheat, especially when soil moisture does not seem to be abundant to a depth of at least 3 or 4 feet. Keeping the land free of weeds or crops for one year will store up soil moisture.

Moisture samplings made by the Lake States Forest Experiment Station indicate that there is a large increment of soil moisture from fall to spring in places where snow accumulates to a depth of 3 to 6 feet. Consequently, if narrow snow-trap plantings were made close to the lee side of places where standard 4-foot-high snow fences had been used the previous winter, it is probable that summer fallowing would not be necessary. Soil samplings made in tree belts in McHenry County, North Dakota from 1936 to 193 9 showed an increase of approximately one inch of water in the soil for every 5 inches of packed snow, and the soil in the top 4 feet had accumulated more moisture in some cases than would be obtained by a full year of summer fallow.

All information available, and this is corroborated by the snow profiles in figure 2, indicates that the snow fences should preferably be planted so that the first shrub row on the windward side is at least 80 to 100 feet from the edge of the road. This distance will give ample storage space even for the heaviest snows that fall in the northern plains and prairies. Care must be taken to plant the trees in a straight line to facilitate cultivation, or if planted on curves the lines of trees must necessarily be smooth and should be staked or marked out before the planting operation begins. Experience by many agencies in this area indicates that spring planting invariably gives better survival than fall planting.

To obtain the maximum results at minimum cost it has been shown that broadleaf trees and shrubs should be one or two years old, with the latter age much preferred for all species listed in table 1, except boxelder, Chinese elm, and perhaps Russian olive, which are fairly satisfactory as one-year-old seedlings. The conifers when planted as bare root stock have shown best results when transplant stock from 3 to 5 years old is used, at which time the trees are from 6 to 14 inches high and have a well developed fibrous root system. Junipers have given good results with 2-1 stock[7], although 1-1, 1-2, and 2-2 stock have also shown good survival and growth. Spruces do best as 2-2, 3-2, or 2-3 stock. Ponderosa and other pines have shown best survival when 2-1, 2-2, or 1-2 stock was used.

Records kept on the many millions of trees of the age classes mentioned above and planted in field shelterbelts in the area under discussion show than one man in an 8-hour day can plant from 300 to 600 trees. If a subsoiler is run down the row previous to setting out the trees, planting speed is stepped up very appreciably and in heavy soils may be doubled.

Planting is done either with shovels, spade, or long-bladed mattocks. A hole is dug large enough to accommodate the roots of the plant, the tree held in the center of the hole, and loose moist soil packed around the tree roots. Some planters hold the tree against the side of the hole and fill in the soil from one side. Others favor building up a cone in the center of the hole and spreading the roots over the cone with uniform distribution, then filling the hole half way, tamping, complete filling, and repeating the tamping. The method which will give reasonably fast speed of planting and maximum survival will depend somewhat on the species of plant and the

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7/ In describing age of conifer planting stock, foresters and nurserymen use the age classifications of 2-1, 2-3, 2-0, etc. For 2-1 stock the first figure means that the trees were grown 2 years in the seedbed and the second figure refers to 1 year of growth in the transplant bed. Thus, a 2-1 tree is three years old. A 2-0 transplant refers to a tree grown only 2 years as a seedling and not transplanted in the nursery.

Table 1.--Shrubs and trees suitable for planting as snow fences in the Northern Great Plains

Number of rows in belt	Type of Wind-break*	Windward			Leeward
		Choice of Species by Rows**			
		Row 1	Row 2	Row 3	Row 4
1	Shrub	Caragana Com.chokecherry Honeysuckle American plum			
2	Shrub, Shrub	Caragana Com.chokecherry Lilac Honeysuckle American plum	American plum Com.chokecherry Russian olive Buffaloberry		
2	Shrub, evergreen	Caragana Com.chokecherry Lilac Honeysuckle American plum	Rocky Mt. redcedar Eastern redcedar Colo. blue spruce Ponderosa pine		
3	Shrub, low tree, shrub.	Caragana Com.chokecherry Lilac Honeysuckle American plum	Green ash Boxelder Hackberry Chinese elm American elm Bur oak	Amer. plum Com.chokecherry Russian olive Buffaloberry Lilac Honeysuckle	
3	Shrub, low tree, evergreen	Caragana Com.chokecherry Lilac Honeysuckle American plum	Green ash Boxelder Hackberry Chinese elm American elm	Rocky Mt. redcedar Eastern redcedar Colo.blue spruce Ponderosa pine	
4	Shrub, low tree, low tree, shrub	Caragana Com.chokecherry Lilac Honeysuckle American plum	Green ash Boxelder Hackberry Chinese elm American elm	Green ash Boxelder Hackberry Chinese elm American elm	American plum Com.chokecherry Russian olive Buffaloberry Lilac Honeysuckle Caragana

*Any one of the three or more species can be selected for any well -drained, non-alkaline soil, ranging in texture from loamy sands to clay loams. Soils with coarse gravel subsoils and shallow topsoil should be avoided. Where it is necessary to cross low spots, plant 1-year-old rooted cuttings of Russian golden willow or other willow varieties. Cottonwood is satisfactory providing it is cut back repreatedly to keep it bushy. Evergreens, especially spruce, could well be limited to a line east of the 100th meridian of longitude.

**Spacing between rows can range from 6 to 10 feet. Spacing between plants in the rows should be as follows: All shrubs in Row 1 should be 2 or 3 feet apart; all shrubs in Rows 2, 3, or 4 can be from 3 to 4 feet apart; all low broadleaf trees in Rows 2 or 3 should be 4, 5, or 6 feet apart. All evergreens should be 4, 5, or 6 feet apart in the row, and 12 to 16 feet away from tall-growing trees like boxelder or elm. These spacing recommendations are contingent upon the assumption that any failed spots will be replanted in the second season.

form of its root system. Machines are available for tree planting but it is questionable whether they should be favored as long as there is a plentiful supply of labor.

Experience of the U. S. Forest Service indicates that more care is needed in handling and planting evergreens than broadleaf species, and survival is generally not as good. The evergreens cannot stand as much root exposure as the broadleaf trees and it is necessary to pack the tree roots in moist sphagnum moss to keep them moist in transit, and to plant them as soon as possible after removal from the nursery, preferably within a few days. Where good cold storage facilities are available, bare-root conifers can be stored as long as 3 or 4 weeks without harm, providing they are stored at temperatures of 34° to 41° F., with sphagnum moss as a packing material.

Somewhat higher survivals can probably be obtained by using balled and burlapped conifer stock ranging from 1-1/2 to 3 feet in height, but the initial cost of such stock is very high and planting costs are almost prohibitive for snow fence purposes. Such large stock may cost from $1.00 to $3.00 per tree, whereas plenty of bids can be obtained on young bare-root transplants at 2 to 5 cents per tree, providing they are purchased in large lots. The tremendous saving of cost in favor of the smaller planting stock will more than offset any advantage the large balled and burlapped stock might have in increased initial survival or lowered costs in replanting or aftercare, such as cultivation. In all planting of snow fences, one must figure on replanting any failed spots in spring of the second year.

After the trees have been planted, it will be necessary to cultivate them for a period of at least 4 to 6 years and any belts with conifer rows will need cultivation for as long as 8 or 10 years. Good cultivation is the key to successful tree planting in prairie regions. From the point of view of having a well kept snow trap that is not so subject to injury by prairie fires that occasionally burn over fields or pastures, most highway departments would probably insist on keeping the outer 6 to 10 feet on each side of the belt free from weeds by cultivation for the entire life of the belt and would fence it with a 4-strand barb wire fence to keep out livestock. Another item of care which is necessary to keep the snow fences from becoming unsightly involves the removal of Russian thistle and other weeds which lodge against the tree belt.

An additional consideration in planting of the snow fences will be the comparative amount of damage done to the trees by rodents, especially jack rabbits. In some sections of the Plains these pests are numerous enough to cause serious injury to certain species, especially the elms, bur oak, and hackberry. In these cases control measures, such as shooting or trapping, may be necessary or resort is made to poisoning done under the supervision of the U. S. Fish and Wildlife Service. A simpler solution may be to avoid planting the species which show high mortality due to rabbit injury.

It may be found advisable to trim back certain of the shrubs, to a height of 12 inches, at the end of the first or second year after planting, in order to promote a dense bushy growth. The relative density of the shrub rows can be used as a criterion to determine whether trimming is necessary. Certain species, such as willows and cottonwood which are planted in low, moist swales) where other species do not grow well), will be very much improved by trimming them back to stimulate a bushy growth.

COSTS OF SNOW FENCE PLANTING

Finney[8] gives considerable data on cost of snow fence planting and indicates that $2.00 per lineal foot of belt is an average initial cost figure. These costs can undoubtedly be slashed tremenduously as has been demonstrated in the shelterbelts of the Prairie States Forestry Project[9] by using somewhat smaller nursery stock such as 2-year-old deciduous seedlings and 3- to 5-year-old conifer transplants. Also, costs can be cut by using a comparatively large percentage of deciduous trees and shrubs which are cheaper to produce and plant, and more adapted to the rigorous climate of the region. Moreover, the deciduous stock does not need the intensive care for as long a period of time as the evergreens.

On the basis of costs estimates of extensive shelterbelt plantings in the Great Plains and making suitable adjustments in adapting them for highway snow fences, it is believed that the cost for such plantings would range from 20 to 75 cents per 100 feet per year. This is based on all estimated initial investments and maintenance costs prorated over 40 years, which is an estimated average effective life of the shrub snow fences.

Since the present system of using slat-wire snow fences costs about 25 cents per 100 feet per year, it is suggested that the simplest type of plantings, consisting of one or two shrub rows might cost no more over a period of years than the slat-wire snow fences. Those belts in which evergreens are used or which consist of 3 or 4 rows would probably cost up 50 or 75 cents per 100 feet of row per year.

If consideration is given to the general aesthetic and wildlife value of such plantings, it is believed there are sufficient advantages to warrant trial of such plantings on a wider scale.

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[8] Finney, E. A. Snow control on highways. Public works. October 1936

[9] From 1935 to 1940, inclusive, over 14,000 miles of belt have been planted by the U. S. Forest Service in the eastern portion of the Great Plains from North Dakota to Texas to protect farms against wind erosion.

OWNERSHIP OF LAND AND LEASE PROBLEM

One factor which may be an obstacle to more extensive planting of tree and shrub snow traps is the question of lease, purchase, or easement of farm land adjoining highways. The experience of the Prairie States Forestry Project might well be cited as opening a possible approach to the problem. Under an agreement between the U. S. Forest Service and the landowner, the Forest Service furnishes the nursery stock, plants it with WPA labor, and provides some labor for aftercare such as hand hoeing. The landowner plows the ground, summer-fallows it in some cases, furnishes the fence material, and does the cultivation. No payment is made for lease of the land, because ownership of the tree belt is vested in the farmer. The tree belt in time becomes effective in wind-erosion control, and the owner is entitled to any products such as fruit (American plum and common chokecherry) or material from thinning of stands for fuel and posts. After the belt reaches maturity and begins to die out, the fuel and post material will go to the farm owner. The multiple benefits derived in soil protection, beautification, fruit and forest products, and as cover and food for upland game, have a strong appeal to the farm owners and they are very ready to offer their land for tree planting.

SUMMARY

The planting of trees and shrubs is proposed for the prairies and plains of northern United States as a possible substitute for standard 4-foot snow fence. The action of wind as influenced by barriers is discussed. Profiles of snowdrifts formed by 18 belts of various ages, species, and number of rows show that a single row of low, dense shrubs is more effective in trapping snow in a limited zone near the belt than a 17-row belt of tall-growing trees devoid of limbs near the ground line. Plantings of 2 to 4 rows are considered more satisfactory than single-row belts. A list of hardy trees and shrubs adapted to the rigorous climate of the Northern Great Plains is given in tabular form, with suggestions for several types of plantings. Recommendations on age class of trees and shrubs, ground preparation, planting, and care are given.

LAKE STATES FOREST EXPERIMENT STATION

SPECIAL WIND STUDY AT HURON ~ S. D.
F. T. FREDRICKSON AND J. W. MACON ~ OBSERVERS

EFFECTIVENESS OF A 50% SOLID BARRIER

IN AN UNUSUALLY STEADY SQUARE-ON WIND OF 38 M.P.H. FOR 5½ HOURS

ALL DATA GIVEN ARE PERCENTAGES OF WIND VELOCITIES IN THE OPEN AT CORRESPONDING HEIGHTS.

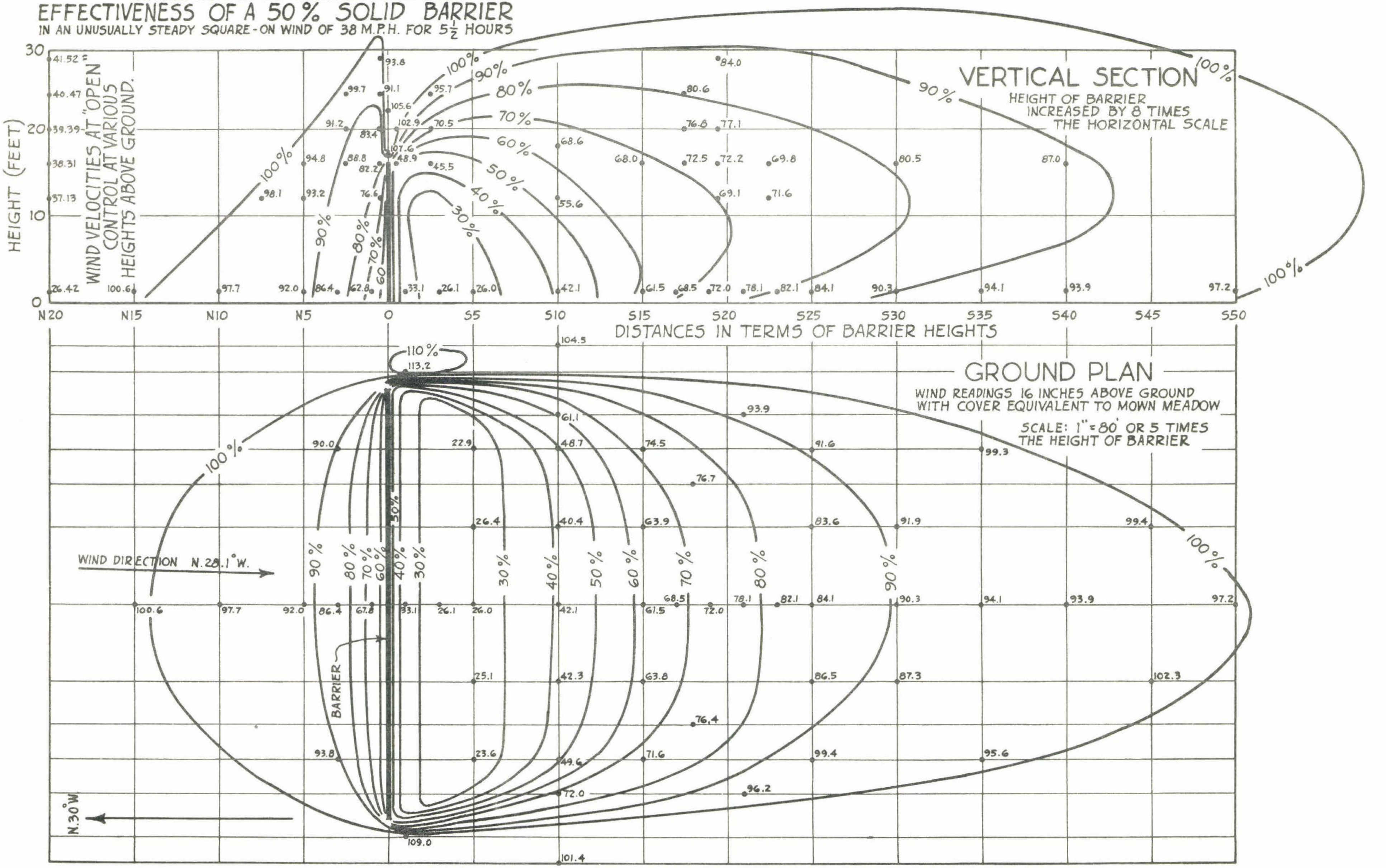

Fig. 1

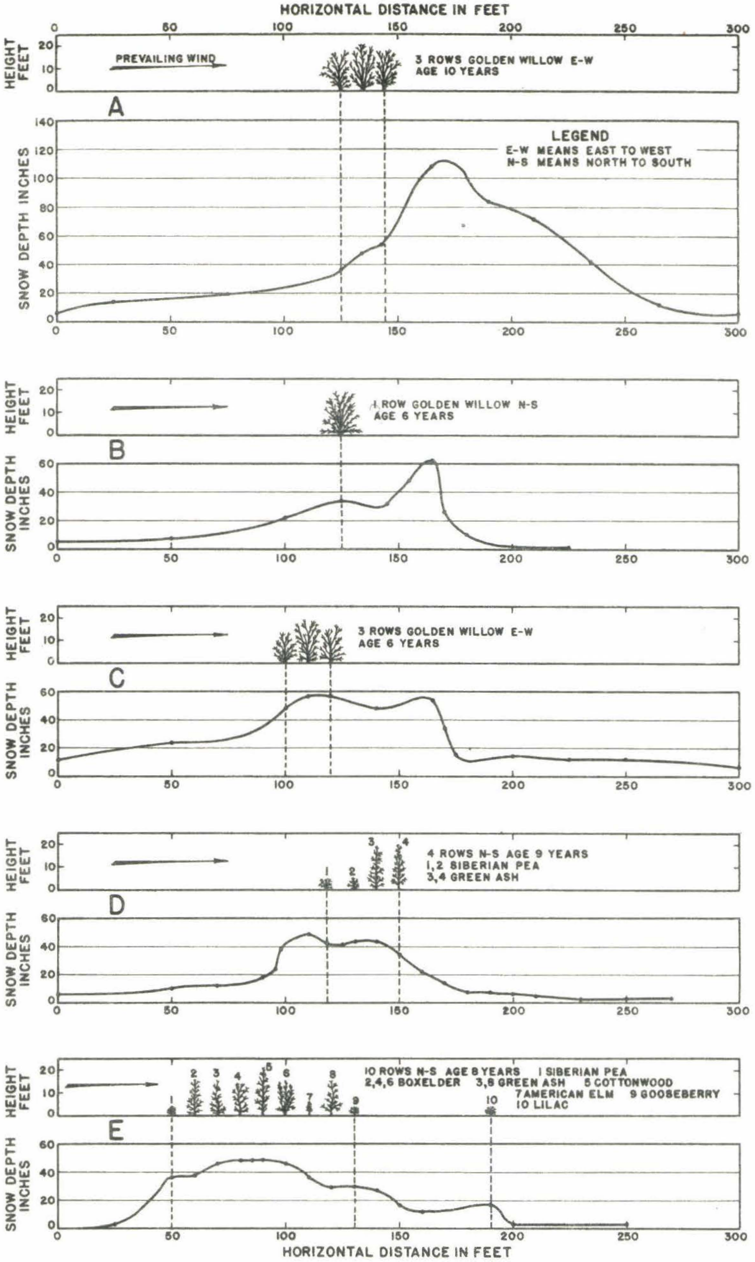

Fig. 2 - Ideal snow profiles formed by young windbreaks of shrubs and trees. North Dakota, March 1939

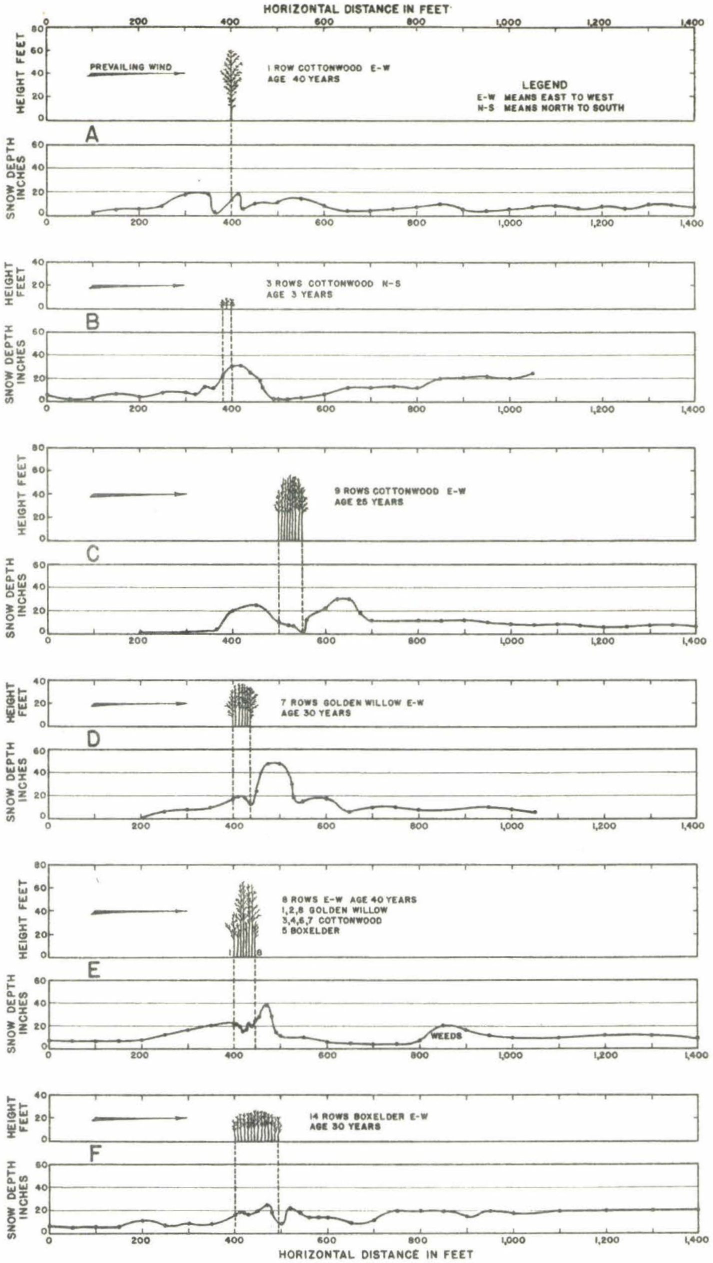

Fig. 3 - Snow profiles formed by tall growing type of tree belt with poor density near ground line. North Dakota, March 1939

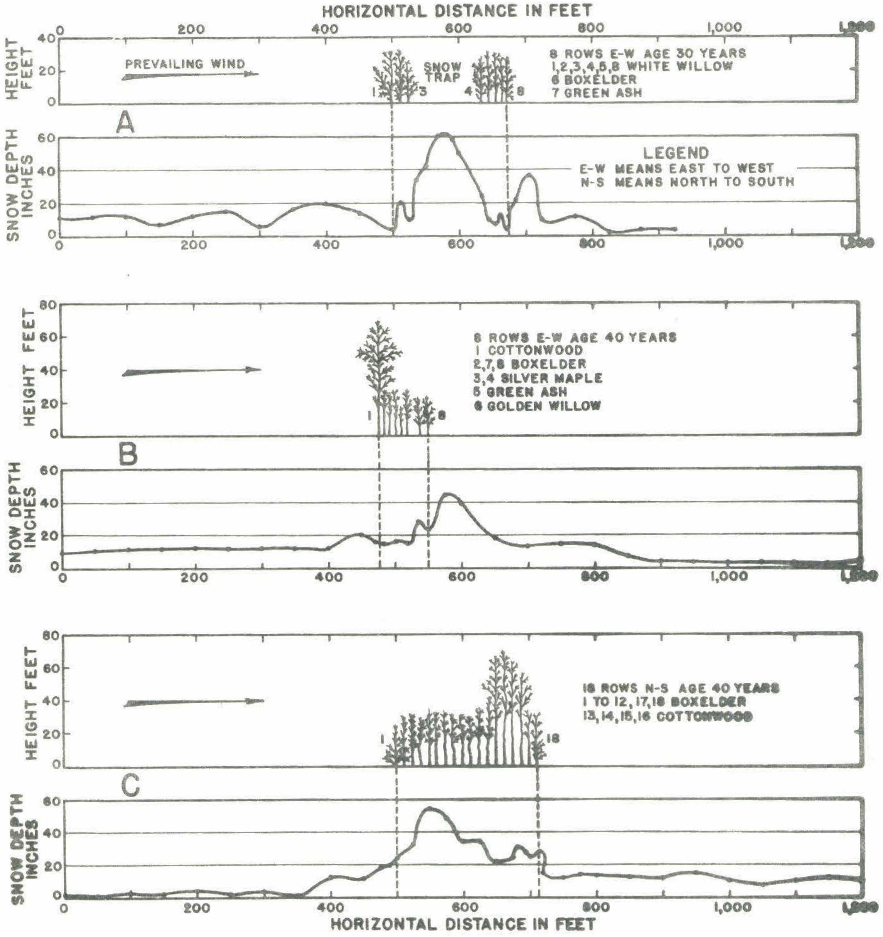

Fig. 4 - Snow profiles in multiple-row shelterbelts. North Dakota, March 1939.

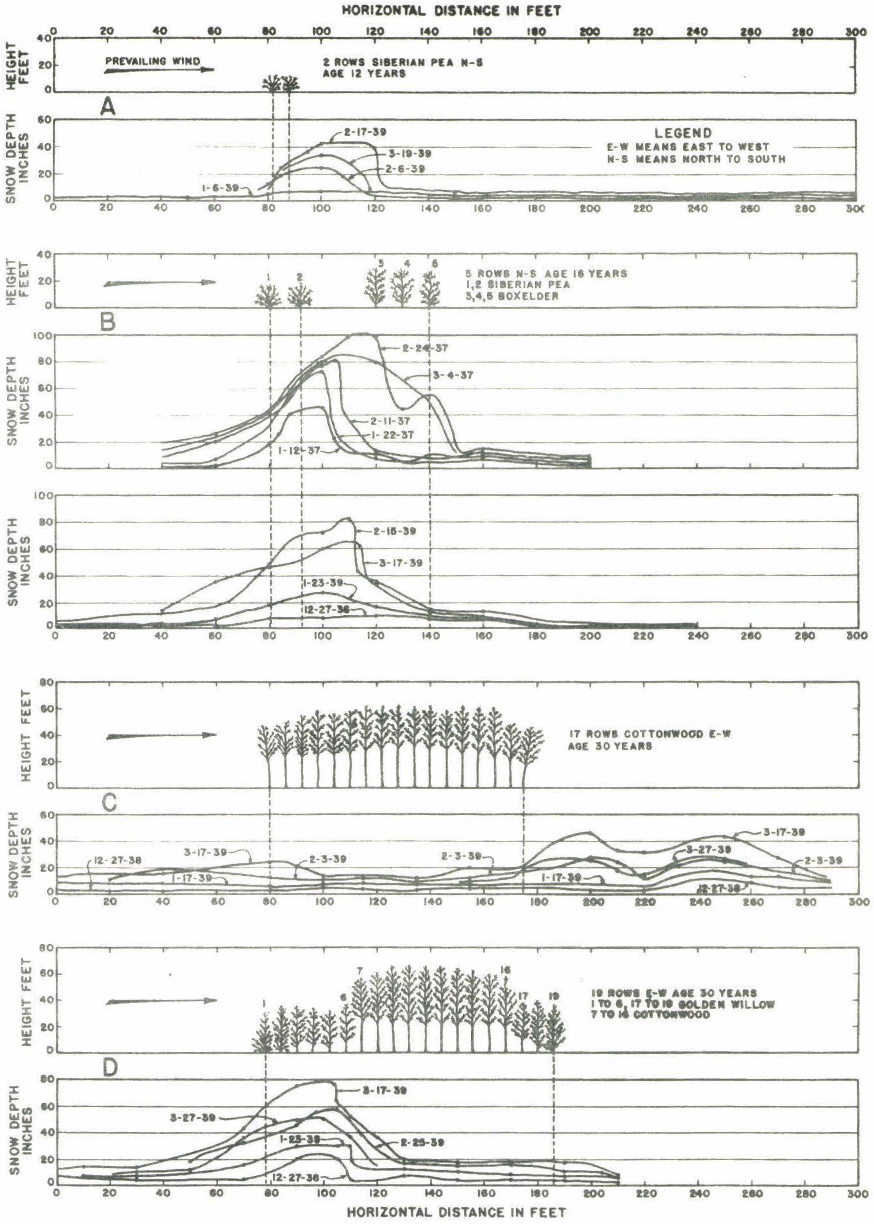

Fig. 5 - Periodic changes in snow profile during the winter months in shelterbelts of various design and composition. North Dakota, 1937, 1938 and 1939.